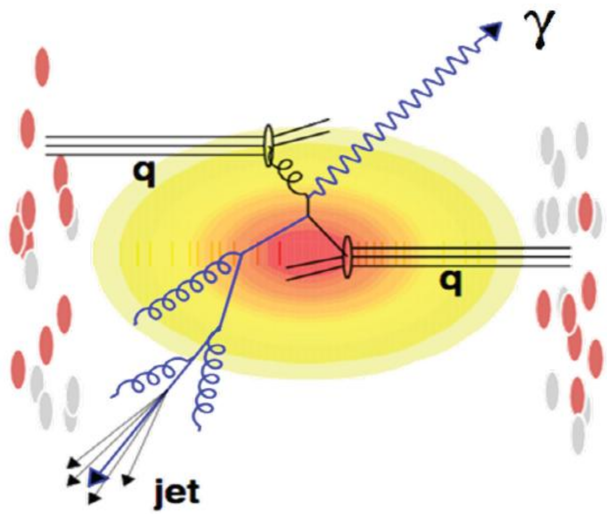
Direct Photon-Hadron Correlations Measured with PHENIX

Megan Connors

For the Phenix Collaboration

April 14, 2011

- Why γ-h
- How we measure γ-h
- What we measured
- How we improved it
- What do we learn

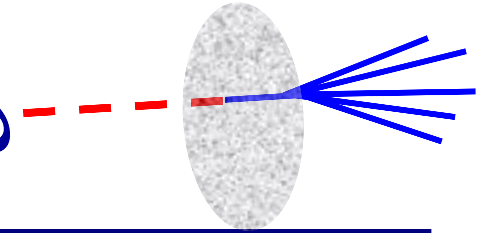


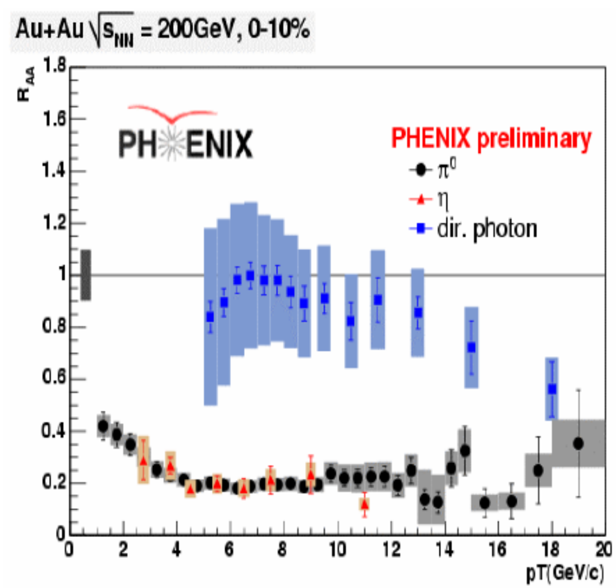
STONY BROOK

XIX International Workshop on Deep-Inelastic Scattering and Related Subjects

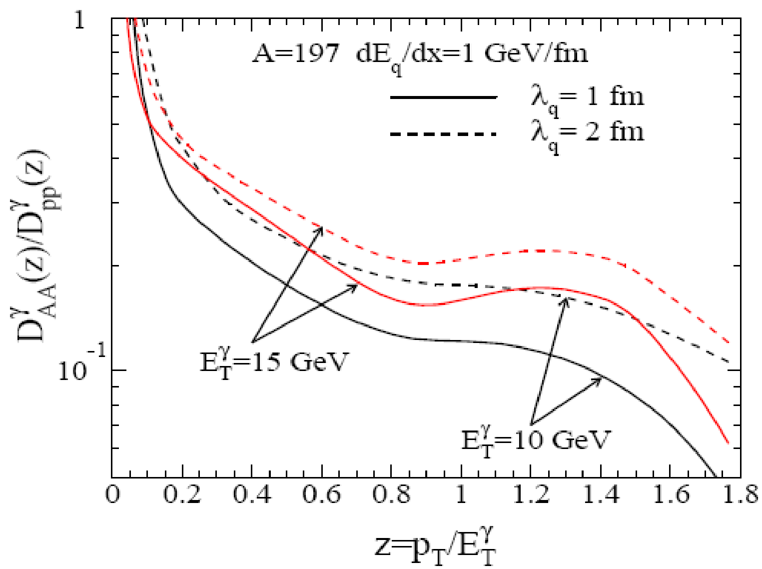
PHENIX

Why Photon Tagged Jets?





X.N. Wang, Z. Huang PRC55 (1997) 3047-3061



- A calibrated probe

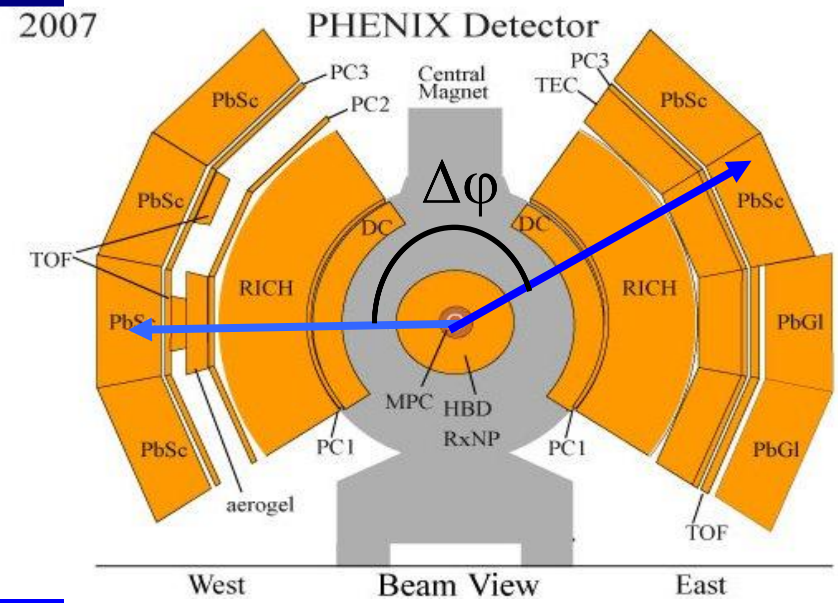
$$\gamma \text{ energy} \approx \text{jet energy}$$

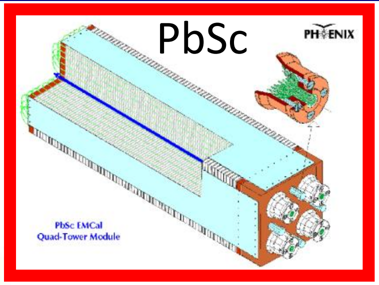
$$z = \frac{p_{hadron}}{p_{jet}} \qquad D_q(z) = \frac{1}{N_{evt}} \frac{dN(z)}{dz}$$

- Also can measure I_{AA}, ratio of the direct photon-hadron yields
- Quantifies the modification

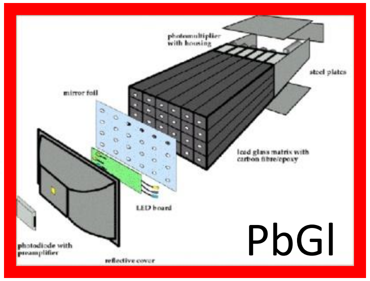
$$I_{AA} = Y_{AA}/Y_{pp} \approx D_{AA}(z)/D_{pp}(z)$$

How we measure γ–h correlations

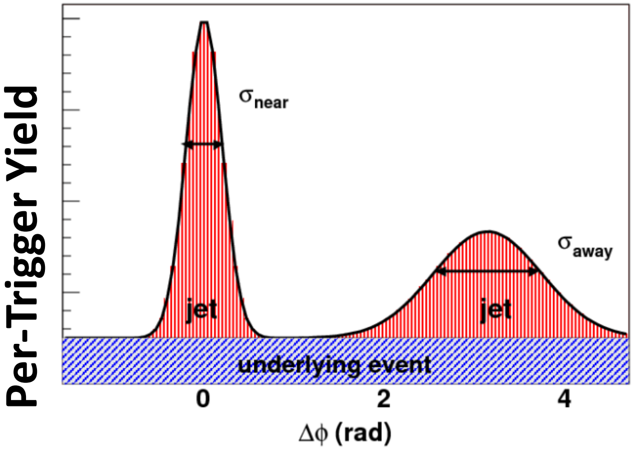




Electromagnetic Calorimeters

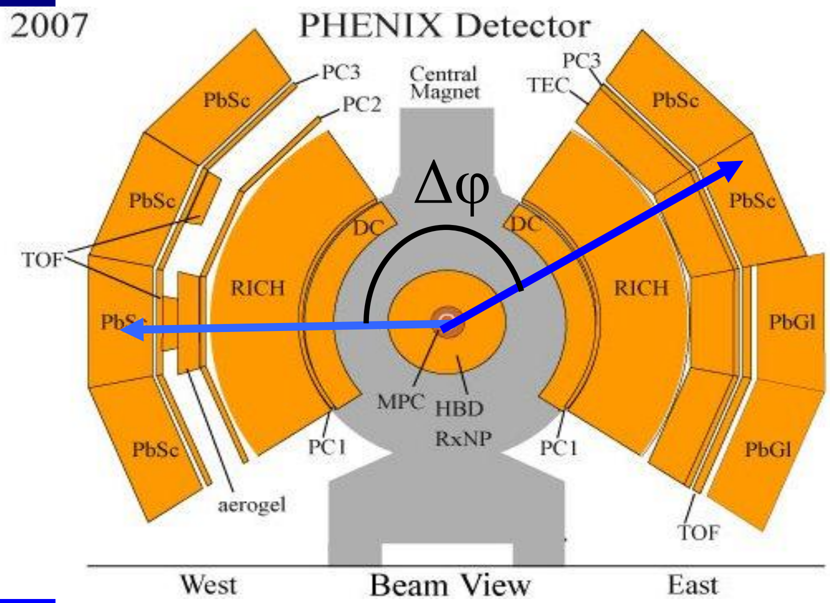


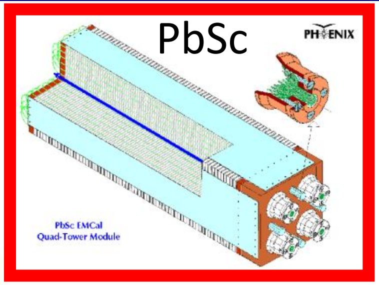
Drift Chamber



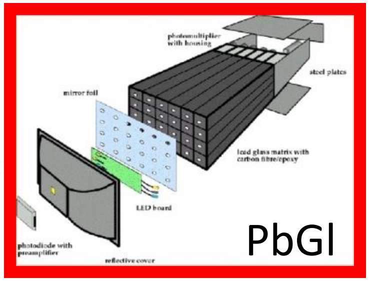
- Trigger on a high p_T (>5GeV/c) inclusive photon
- Measure $\Delta\phi$ between photon and all hadrons in the event within a certain p_T range
- Event mixing corrects for acceptance and combinatorial pairs

How we measure γ–h correlations

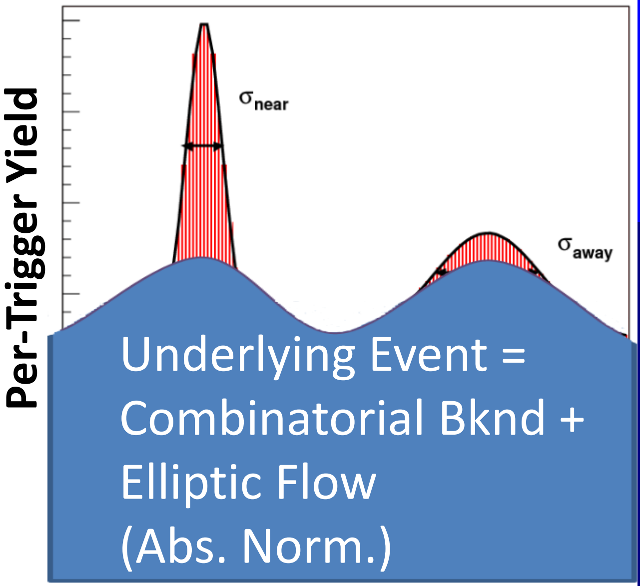




Electromagnetic Calorimeters

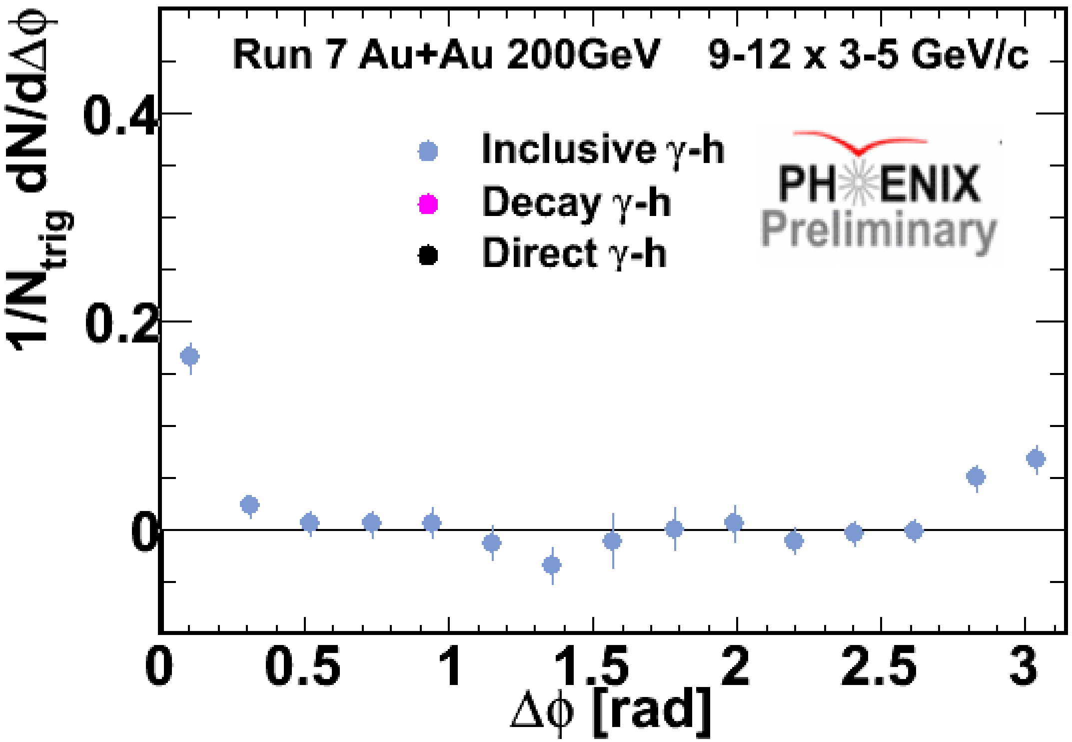


Drift Chamber



- Trigger on a high p_T (>5GeV/c) inclusive photon
- Measure Δϕ between photon and all hadrons in the event within a certain p_T range
- Event mixing corrects for acceptance and combinatorial pairs

γ-h Δφ Correlations via Statistical Subtraction Method

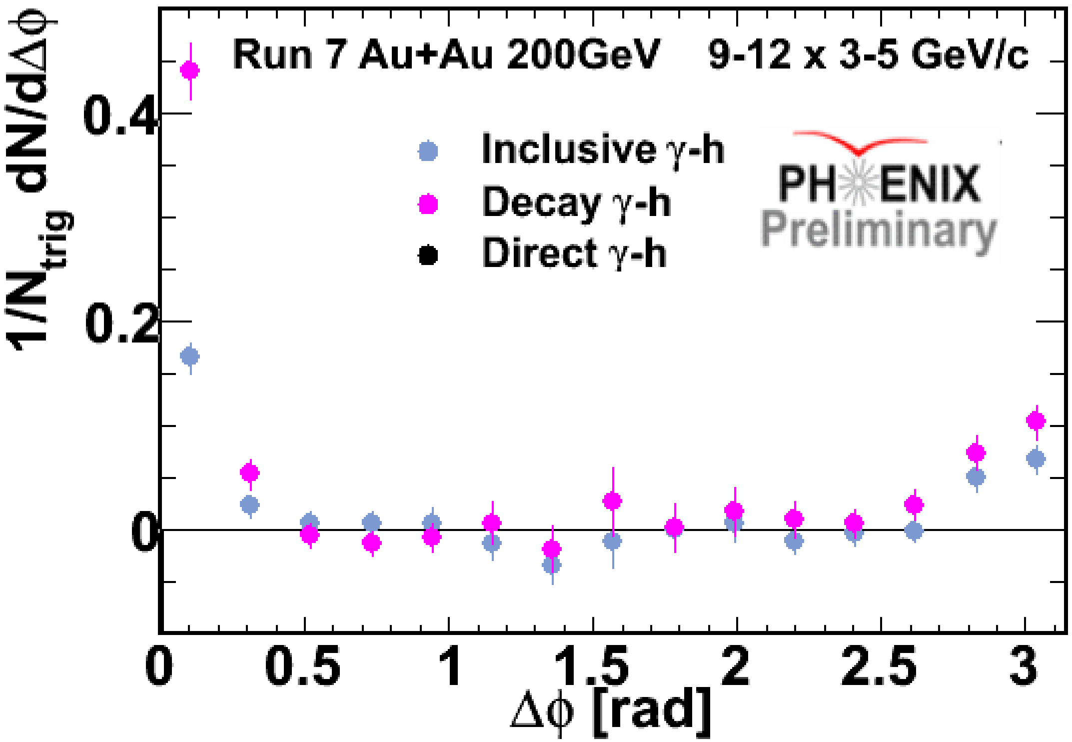


- Inclusive

$$Y_{incl} = \frac{N_{dir}}{N_{incl}} Y_{dir} + \frac{N_{dec}}{N_{incl}} Y_{dec}$$

A. Adare et al (PHENIX) PRC 80, 024908 (2009)

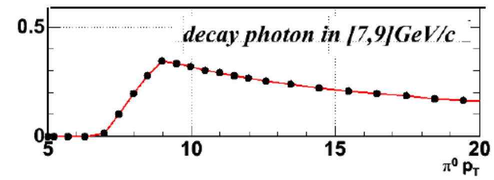
γ-h Δφ Correlations via Statistical Subtraction Method



- Inclusive

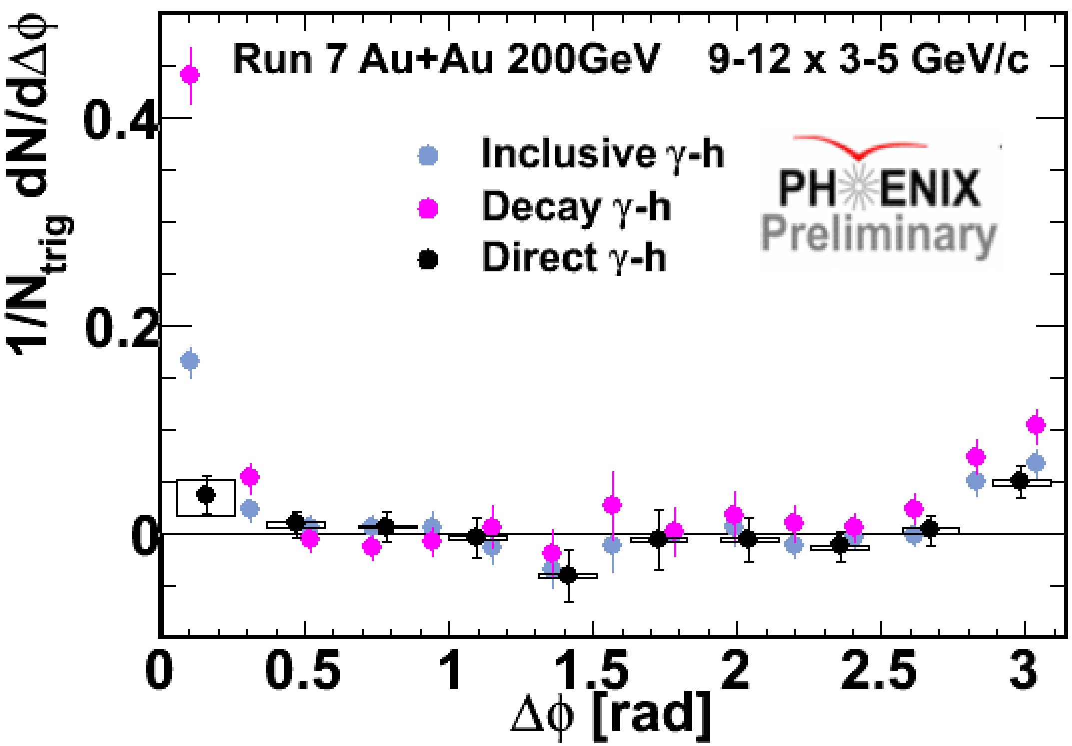
$$Y_{incl} = \frac{N_{dir}}{N_{incl}} Y_{dir} + \frac{N_{dec}}{N_{incl}} Y_{dec}$$

- Decay



A. Adare et al (PHENIX) PRC 80, 024908 (2009)

γ-h Δφ Correlations via Statistical Subtraction Method



Little to no near side yield

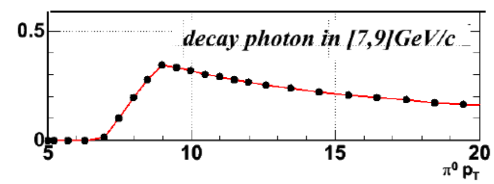
Measure the away side yield

A. Adare et al (PHENIX) PRC 80, 024908 (2009)

- Inclusive

$$Y_{incl} = \frac{N_{dir}}{N_{incl}} Y_{dir} + \frac{N_{dec}}{N_{incl}} Y_{dec}$$

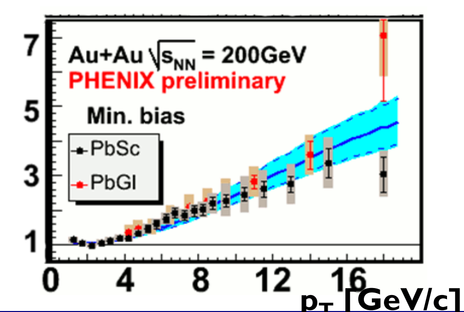
- Decay



- Direct γ-h

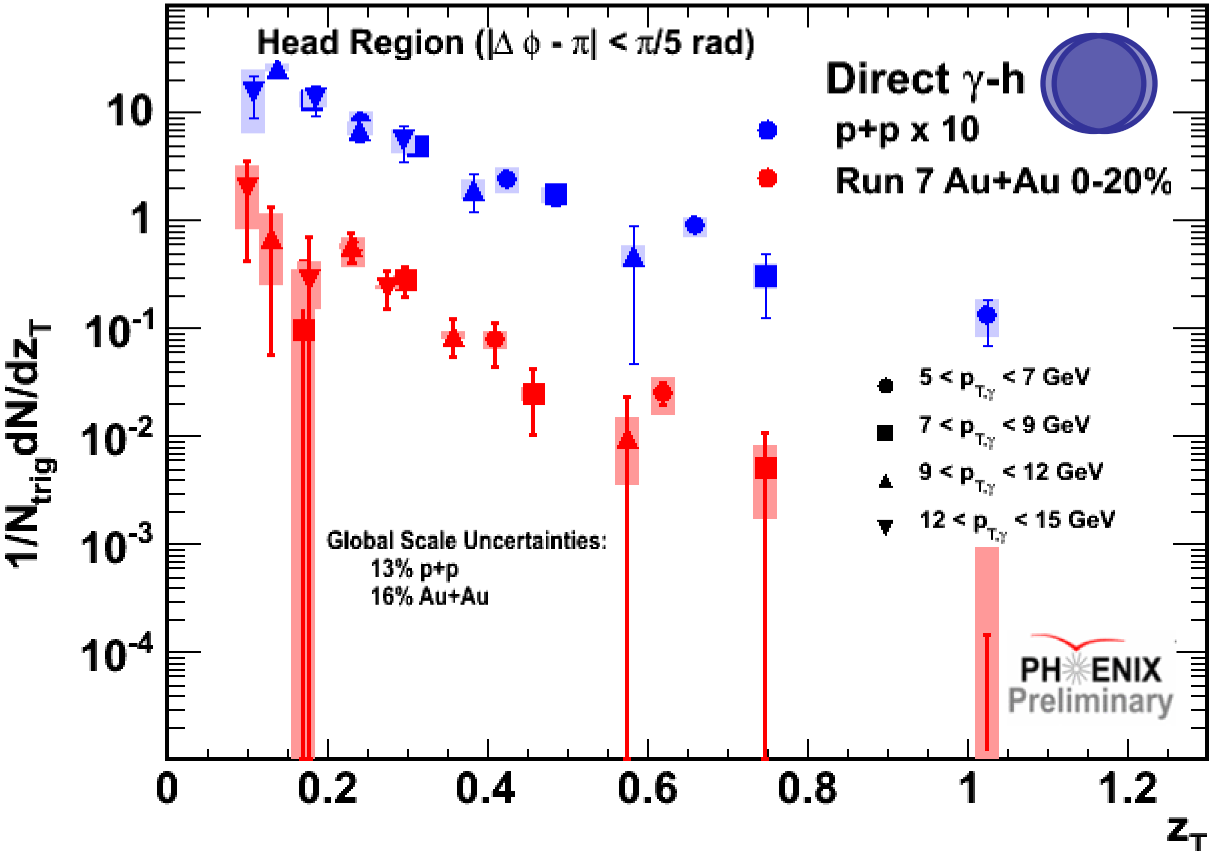
$$\boxed{Y_{direct} = \frac{R_\gamma Y_{incl} - Y_{decay}}{R_\gamma - 1}}$$

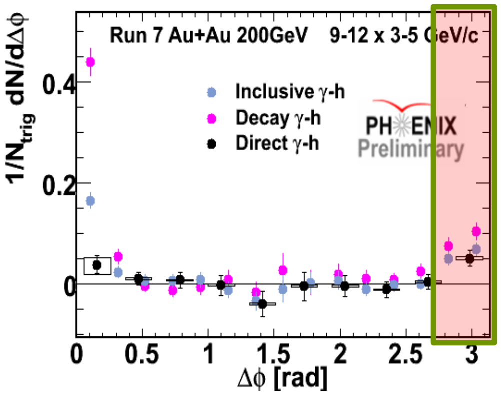
$$R_\gamma = \frac{N_{incl}}{N_{decay}}$$



Away-side Fragmentation Function

- Measurement of modified FF in Au+Au compared to p+p





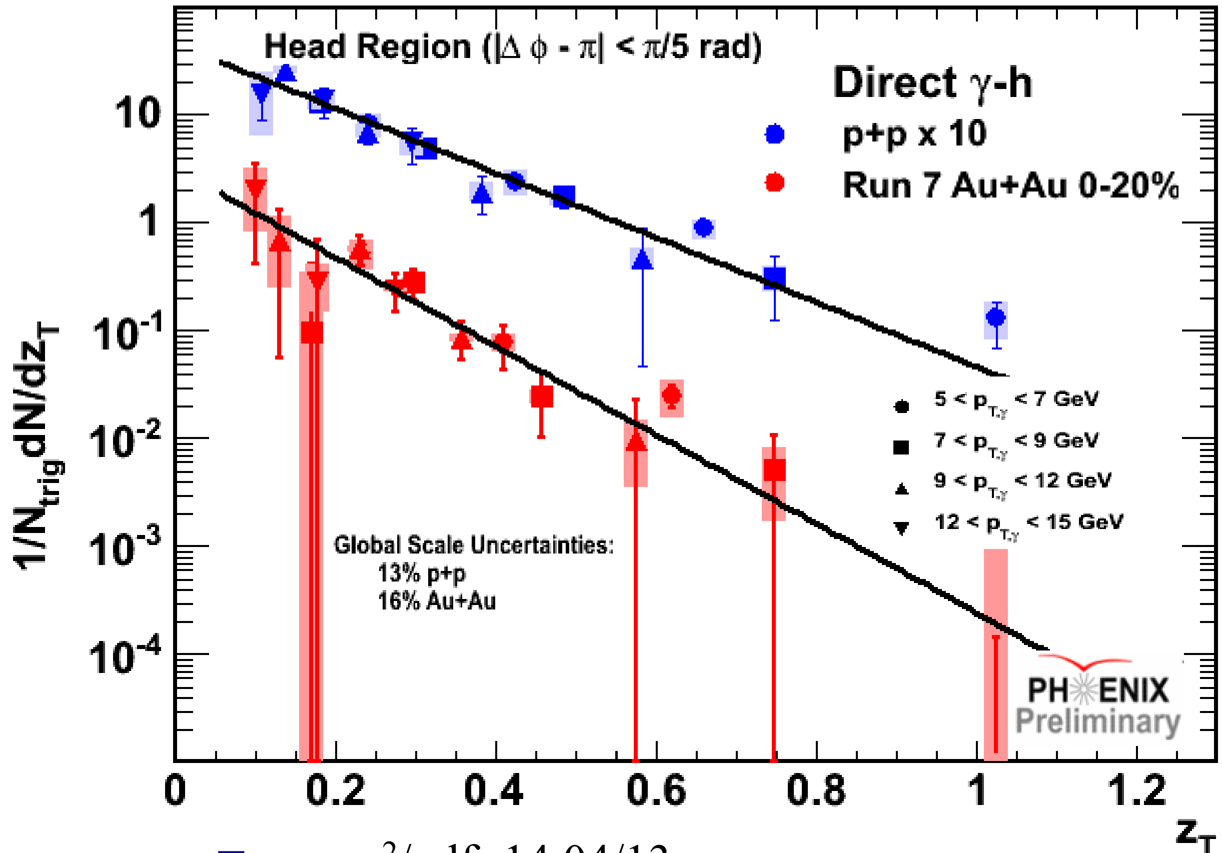
$$z_T = \frac{p_T^h}{p_T^\gamma}$$

$$p_T^\gamma \approx p_T^{jet}$$

$$D_q(z_T) = \frac{1}{N_{evt}} \frac{dN(z_T)}{dz_T}$$

Slope comparison $\frac{dN}{dz_T} = Ne^{-bz_T}$

- Fit a universal curve for all jet energies
- p+p slope of 6.89 ± 0.64 more consistent with quark fragmentation of b=8 than b=11 for gluons
- Slope of Au+Au is 9.49 ±1.37
- Au+Au slope is ~1.3σ higher than p+p



- pp: χ^2/ndf=14.04/13
- AuAu: χ^2/ndf=10.0/13

Modified Fragmentation Function

- $I_{AA} < 1$ shows suppression of the away side

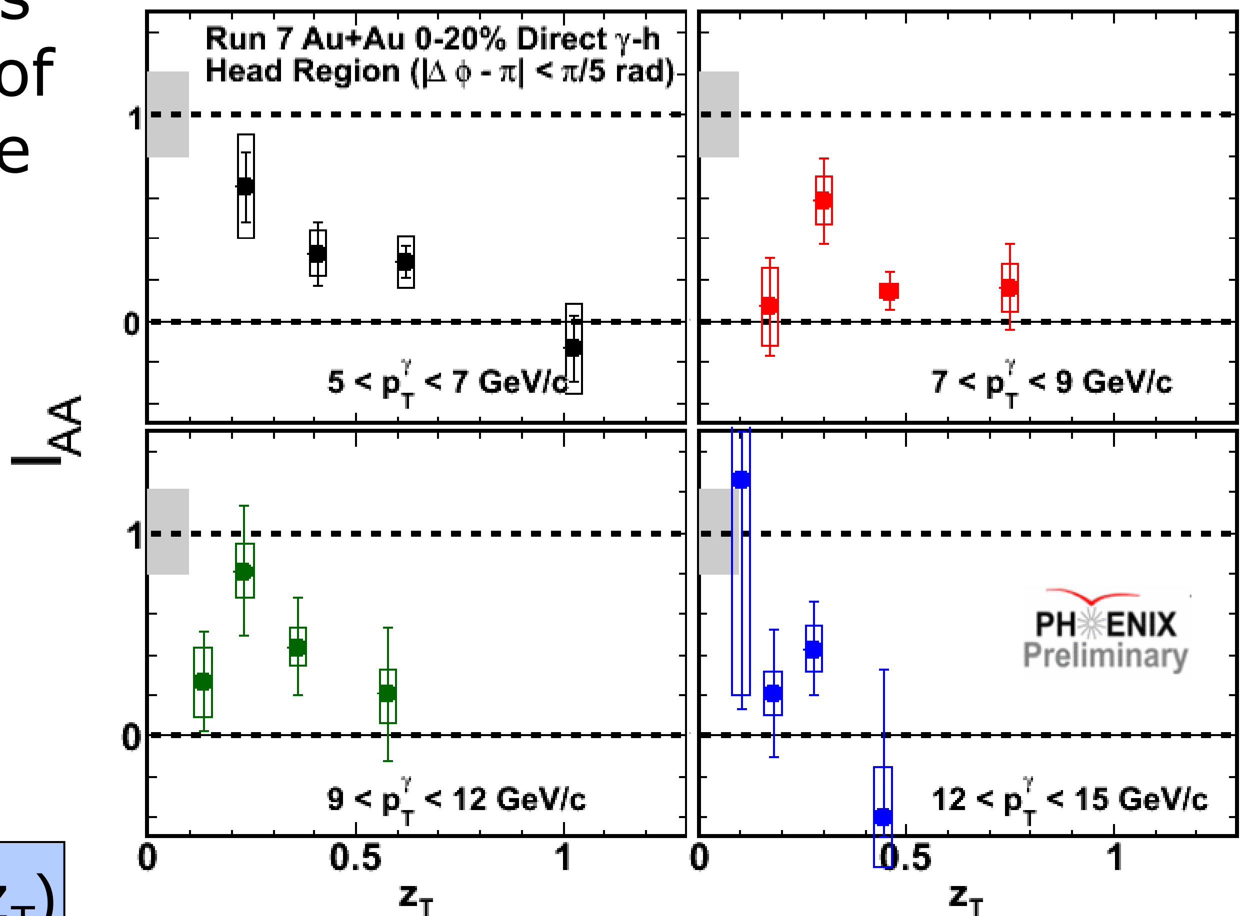
$$z_T = \frac{p_T^h}{p_T^\gamma}$$

$$p_T^\gamma \approx p_T^{jet}$$

$$D_q(z_T) = \frac{1}{N_{evt}} \frac{dN(z_T)}{dz_T}$$

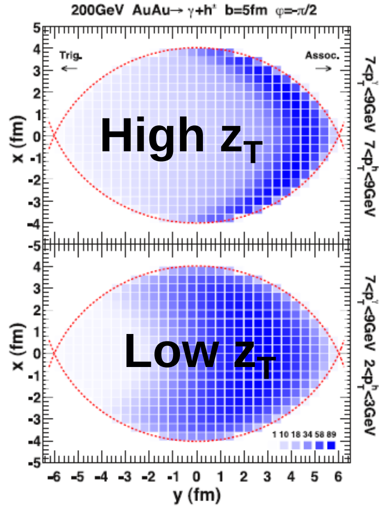
$$I_{AA} = Y_{AA}/Y_{pp}$$

$I_{AA} \sim D_{AA}(z_T)/D_{pp}(z_T)$



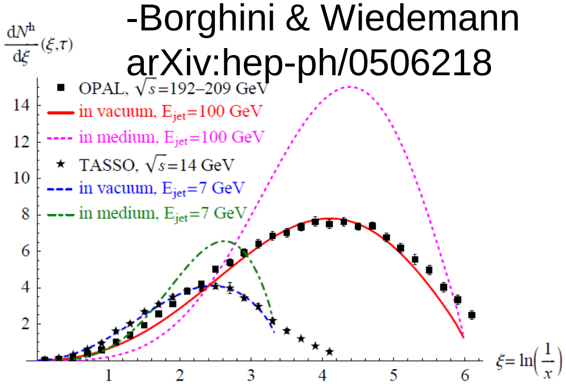
Comparison to Models

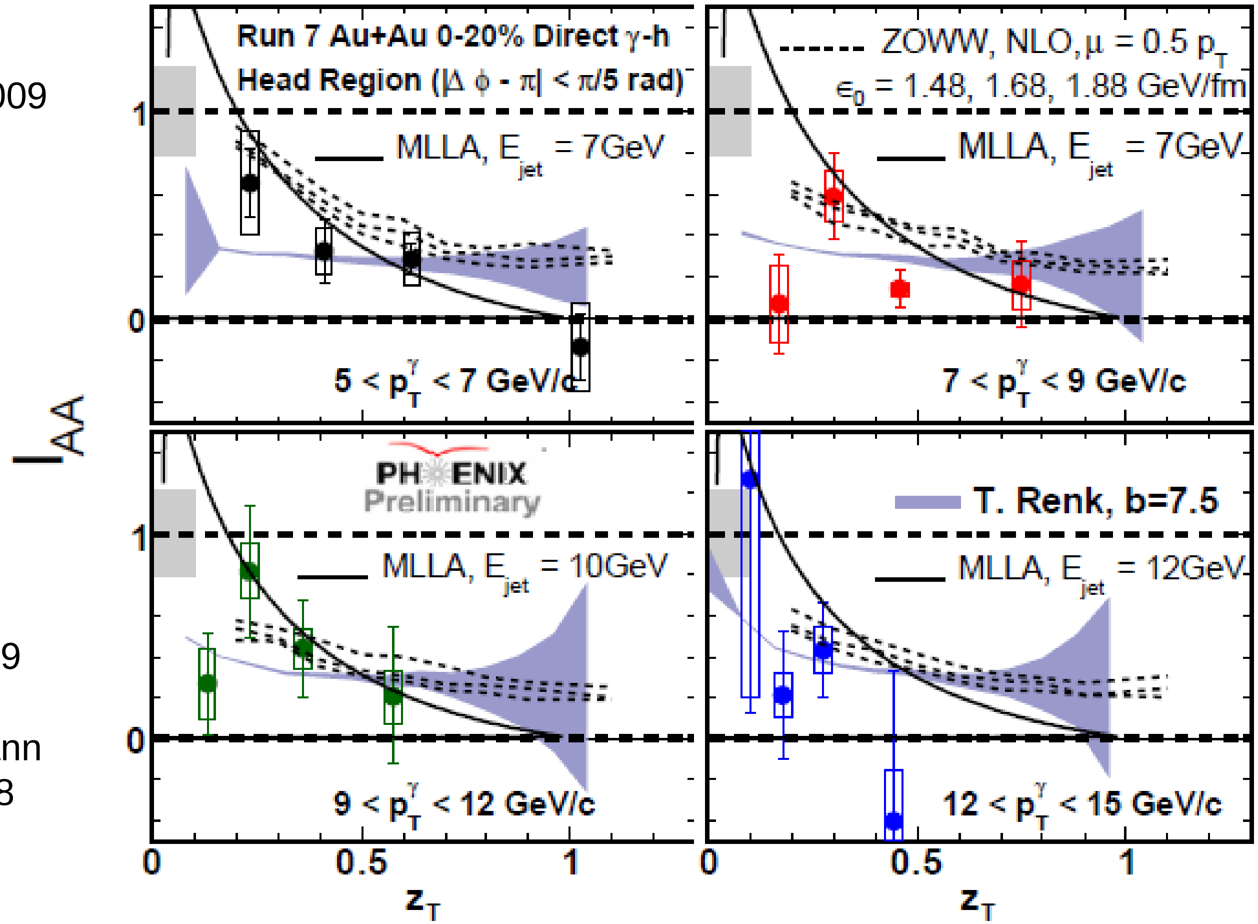
ZOWW PRL103:032302,2009



Renk, PRC80:014901,2009

-Borghini & Wiedemann
arXiv:hep-ph/0506218



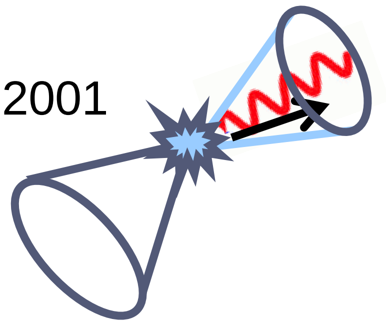


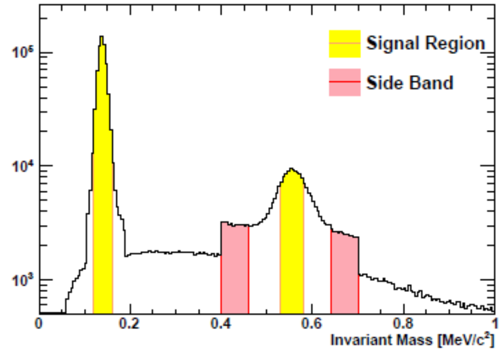
- Models diverge at low z_T

Event by Event Techniques in p+p

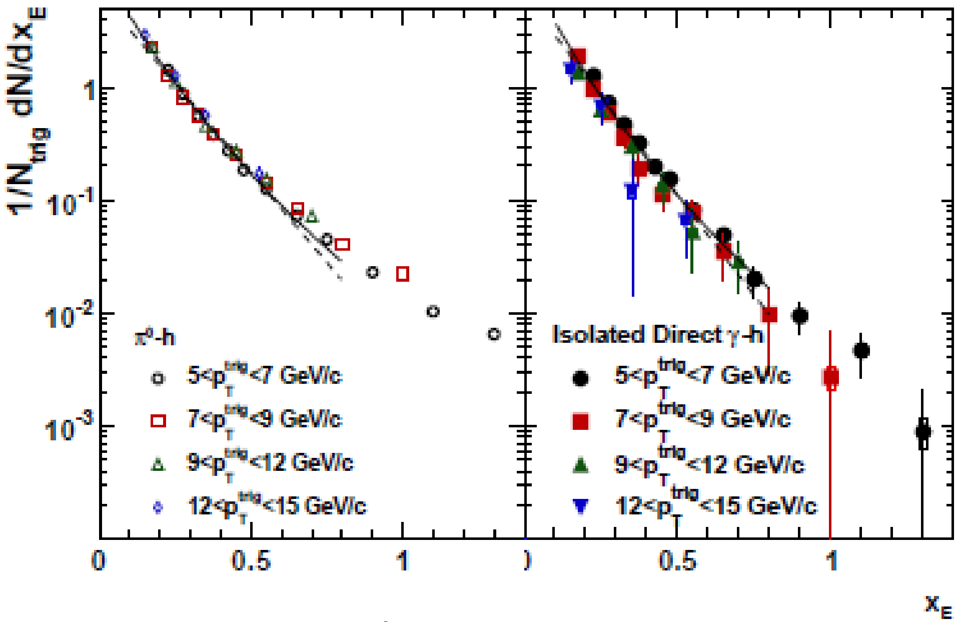
- Remove the decay background on an event by event basis
  - Tagging the photon as a meson decay by finding its partner
  - Isolation cut: $E_{tot}(R=0.3)<10\%\ E\gamma$
    - Also reduces fragmentation photon component
- Increasing the S/B reduces the systematic uncertainties

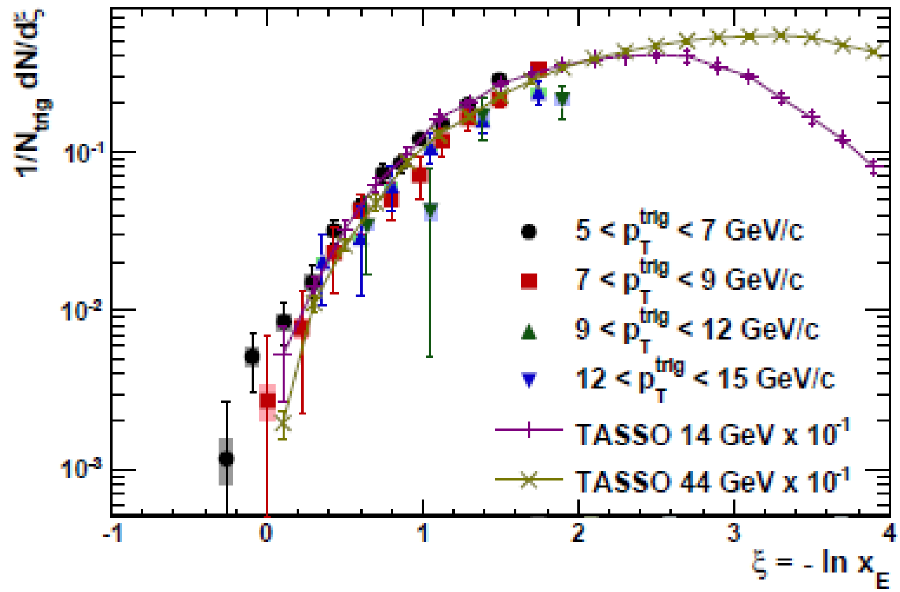
Adare et al PhysRevD.82.072001





Measure the Quark Fragmentation Function

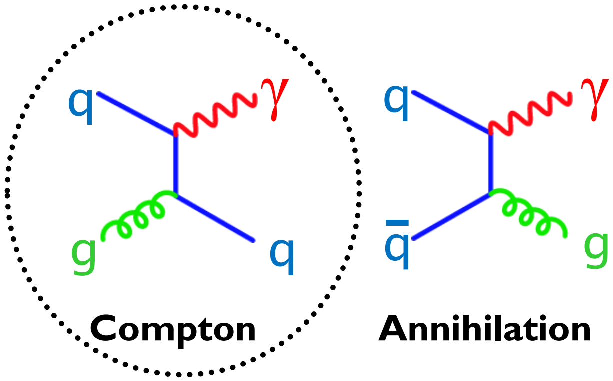


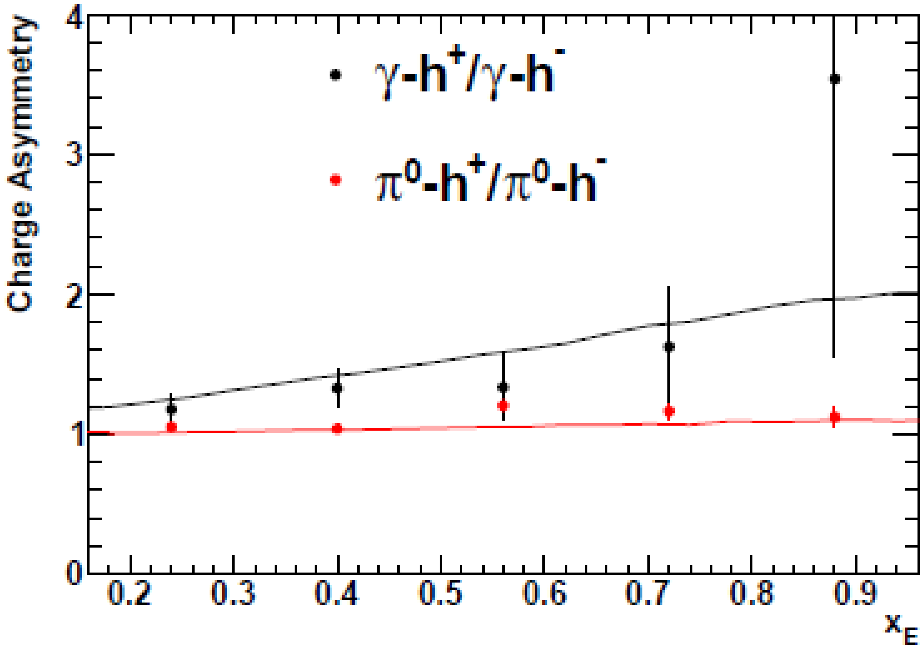


- $x_E = -p_T^h/p_T^\gamma \cos(\Delta\phi) \sim z_T$
- γ-h is steeper than π^0-h!
- x_E universal scaling!
- $$\frac{dN}{dx_E} = Ne^{-bx_E}$$ b=8.2±0.3

- Plot with MLLA variable $\xi = -\ln x_E$
- Good agreement with TASSO measurement (e^+e^-)
- Baseline for E-loss in Au+Au

Quark Jets and Charge Asymmetry

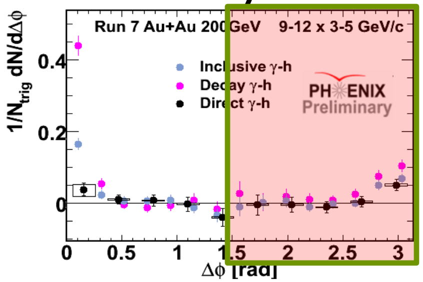




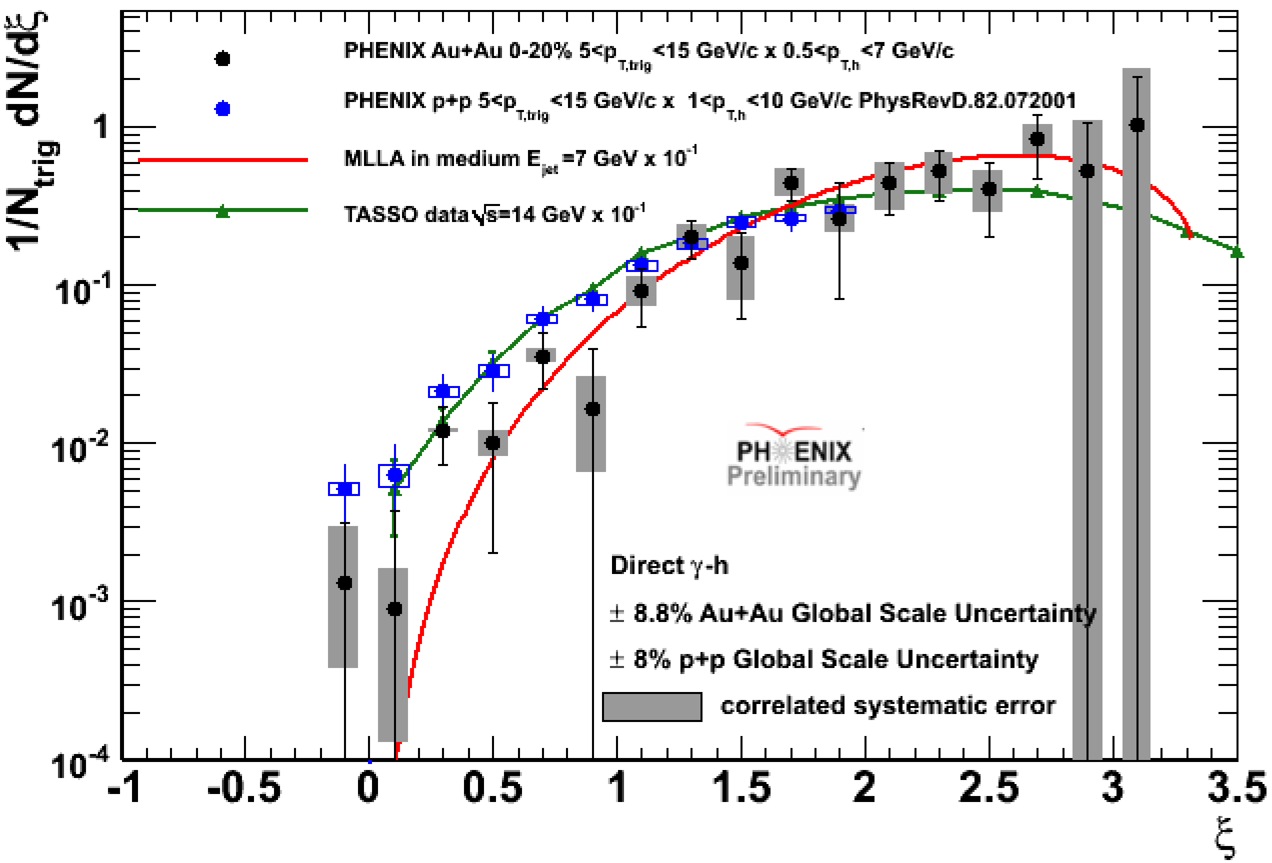
- Compton scattering dominates the direct photon production
- Charge asymmetry of valence quark (u:d = 2:1) should reflect in final state charged hadrons
- An excess of positive charge yields in γ-h!
- Consistent with LO+k_T model prediction
- The recoil jet is dominated by quark fragmentation!

Modified fragmentation function

- Full awayside



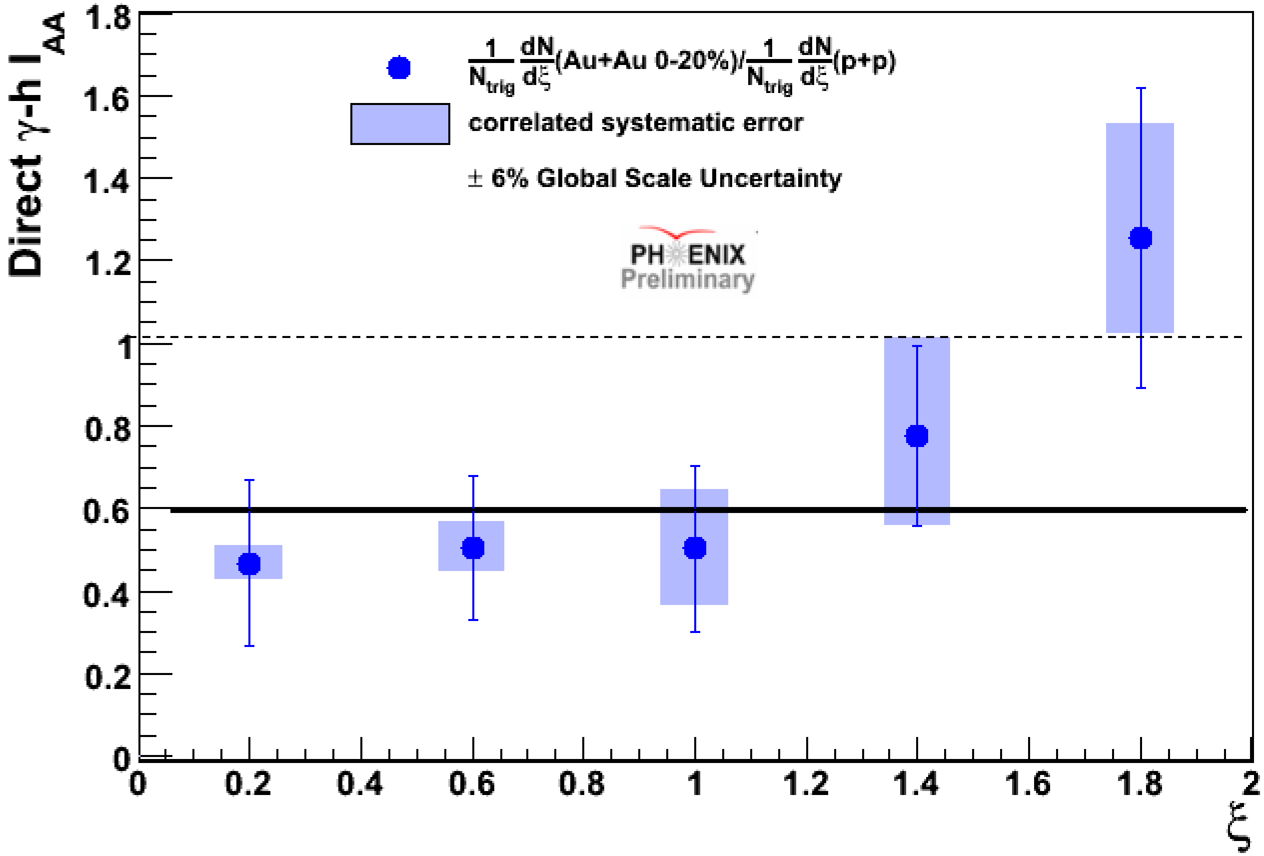
- We know there is suppression at low ξ (high z_T) but what about the shape?
- Take the ratio of Au+Au to p+p to measure modification of the fragmention function…



- Extended Au+Au measurement to high ξ (low z_T) by extending lower limit of p_{Th} from 1 to 0.5GeV/c

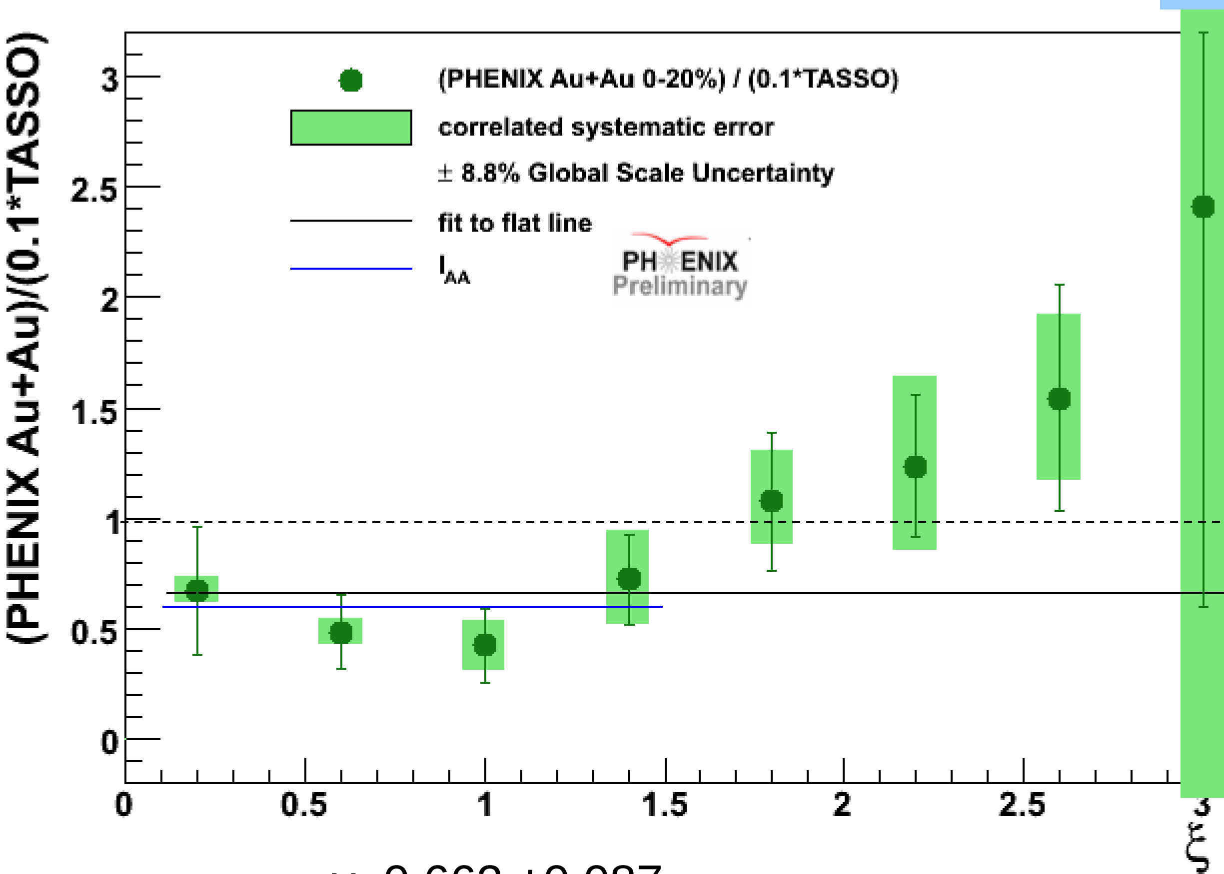
I_{AA}

- With combined trigger bins 5-15GeV/c and full awayside we see an increase at high ξ
- Fit to a flat line gives a χ^2/NDF=4.85/4 and an "average" I_{AA}=0.598 ±0.095



Comparison to TASSO

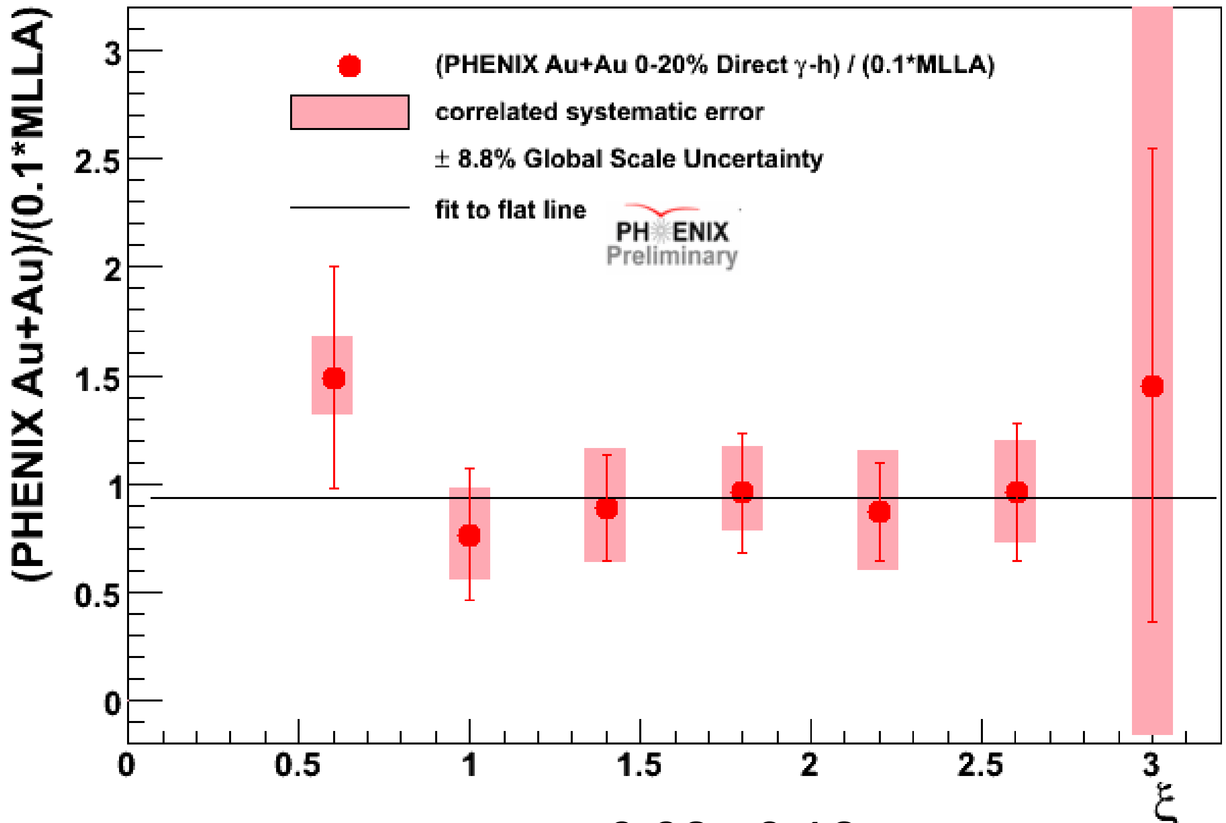
- Extends to higher ξ
- Low ξ is consistent with I_{AA}
- But enhancement at high ξ
- Shape is modified!
- Found E_{loss}!



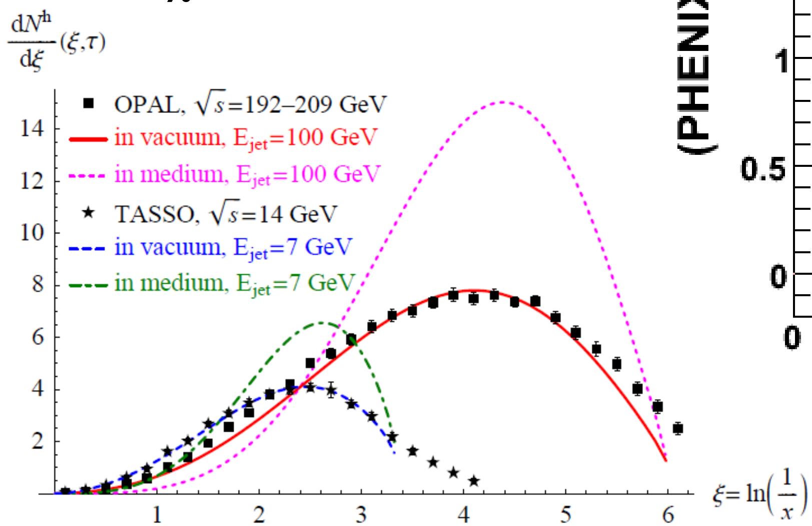
y=0.662 ±0.087
$\chi2$/NDF=12.16/7

Compared to in Medium prediction

- MLLA forces yield to zero at $\xi=0$
- But at high ξ MLLA curve predicts the shape well $\chi^2/NDF=0.84$

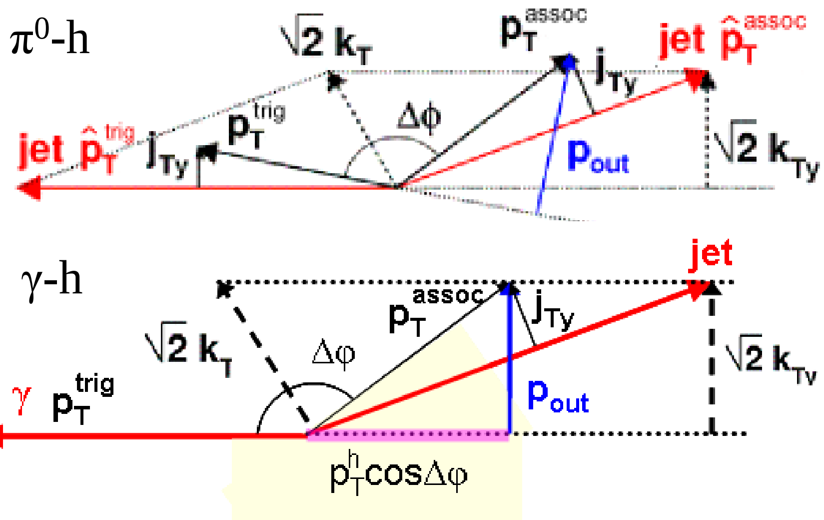


y=0.93 ±0.12

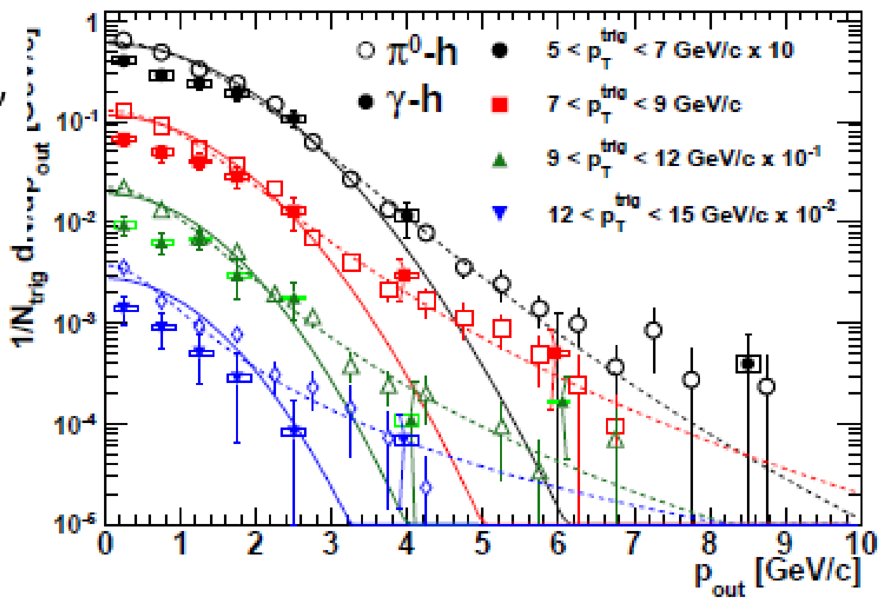


Borghini and Wiedemann arXiv:hep-ph/0506218

Measuring p_{out} and k_T in p+p



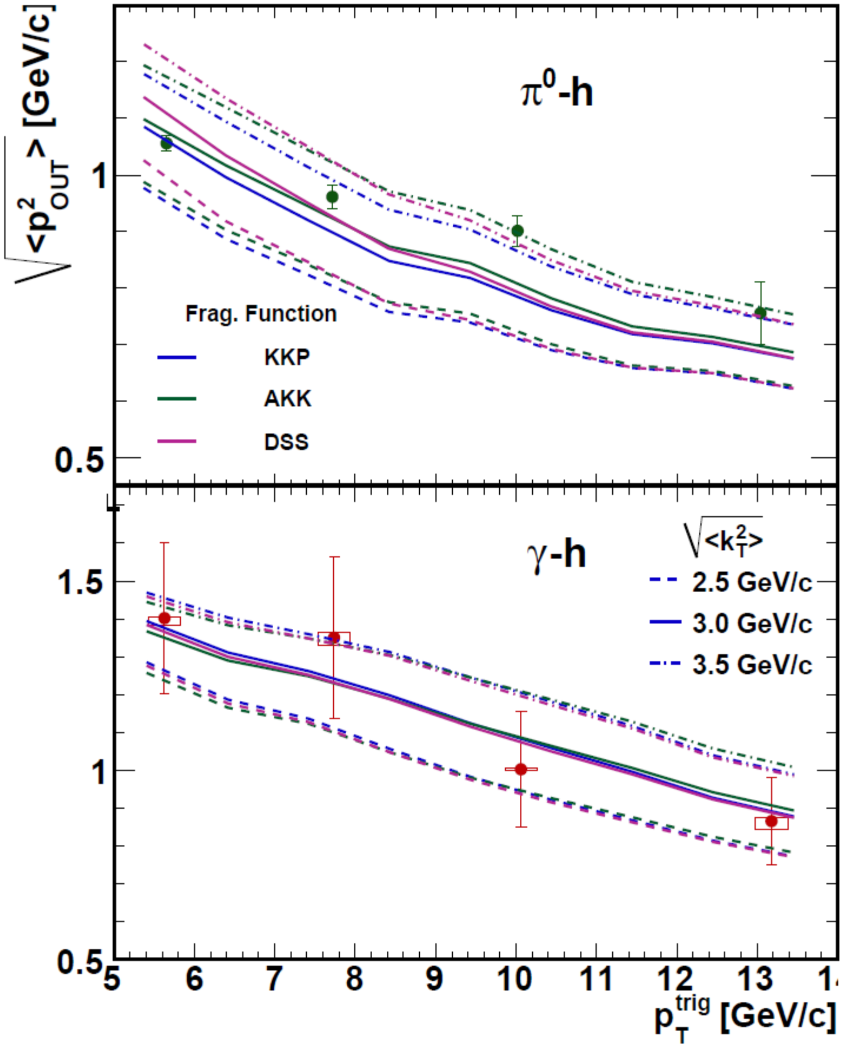
$$|p_{\rm out}| = |p_T^{\rm assoc}| \sin\Delta\phi$$



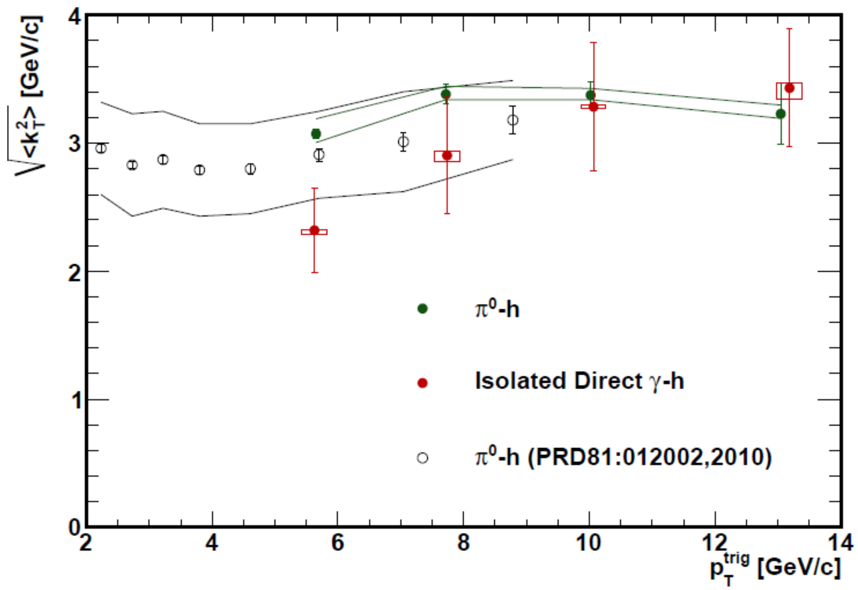
- Fit p_{out} with Gaussian and Kaplan functions
  $$C(1 + p_{\rm out}^2/b)^{-n}$$
- Actually obtain widths from CF(Δφ)

A. Adare et al. **PhysRevD.82.072001**

Extracting k_T



- LO+k_T smearing model
- k_T~3 GeV/c



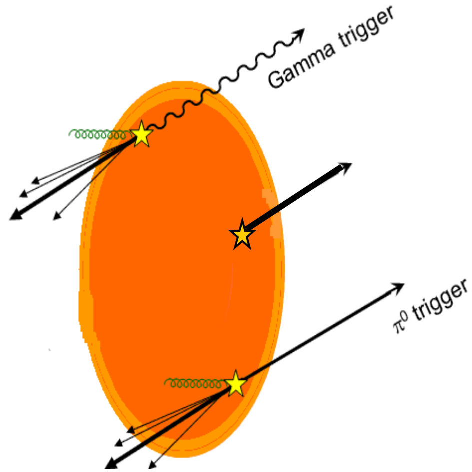
Conclusions

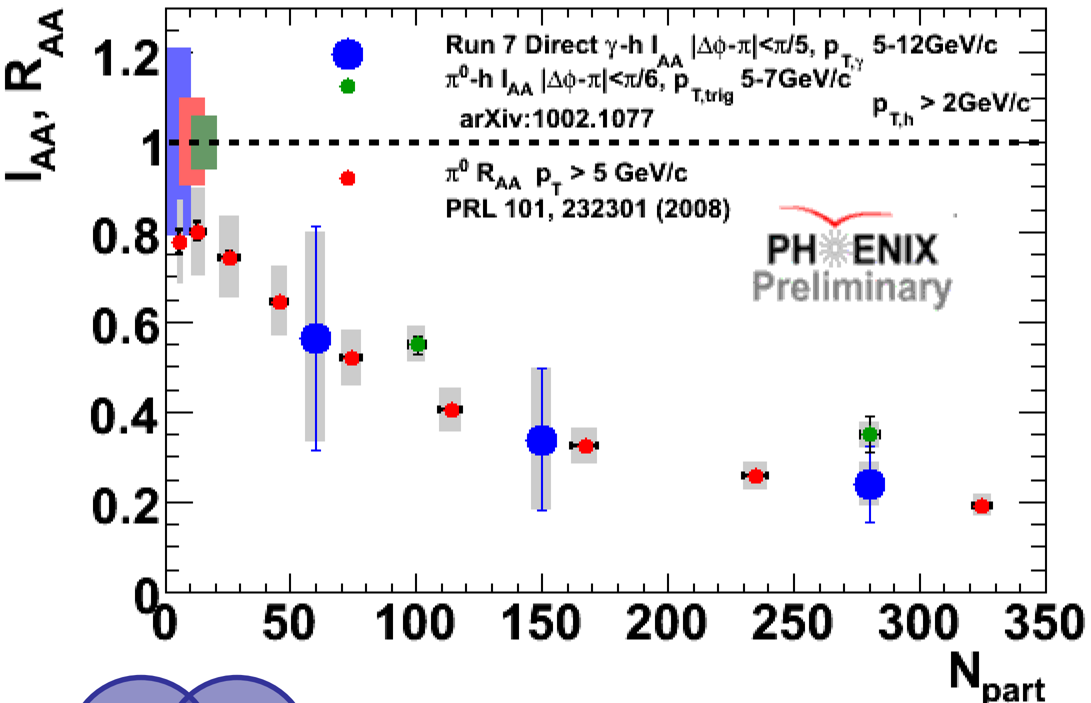
- Measured quark fragmentation function in p+p
- Measured p_{out} and determined k_T(~3 GeV/c) from p+p (Au+Au next)
- Yield in Au+Au is suppressed at low ξ but the shape of the fragmentation function appears to be unmodified
- Moving toward high ξ the shape does change and enhancement is observed
- More to come from the direct γ-h analysis
  - Largest Au+Au RHIC data set collected: Run 10

Back up Slides

Centrality Dependence

- Direct γ-h I_{AA} also consistent with π^0 R_{AA}
- Surface Bias?



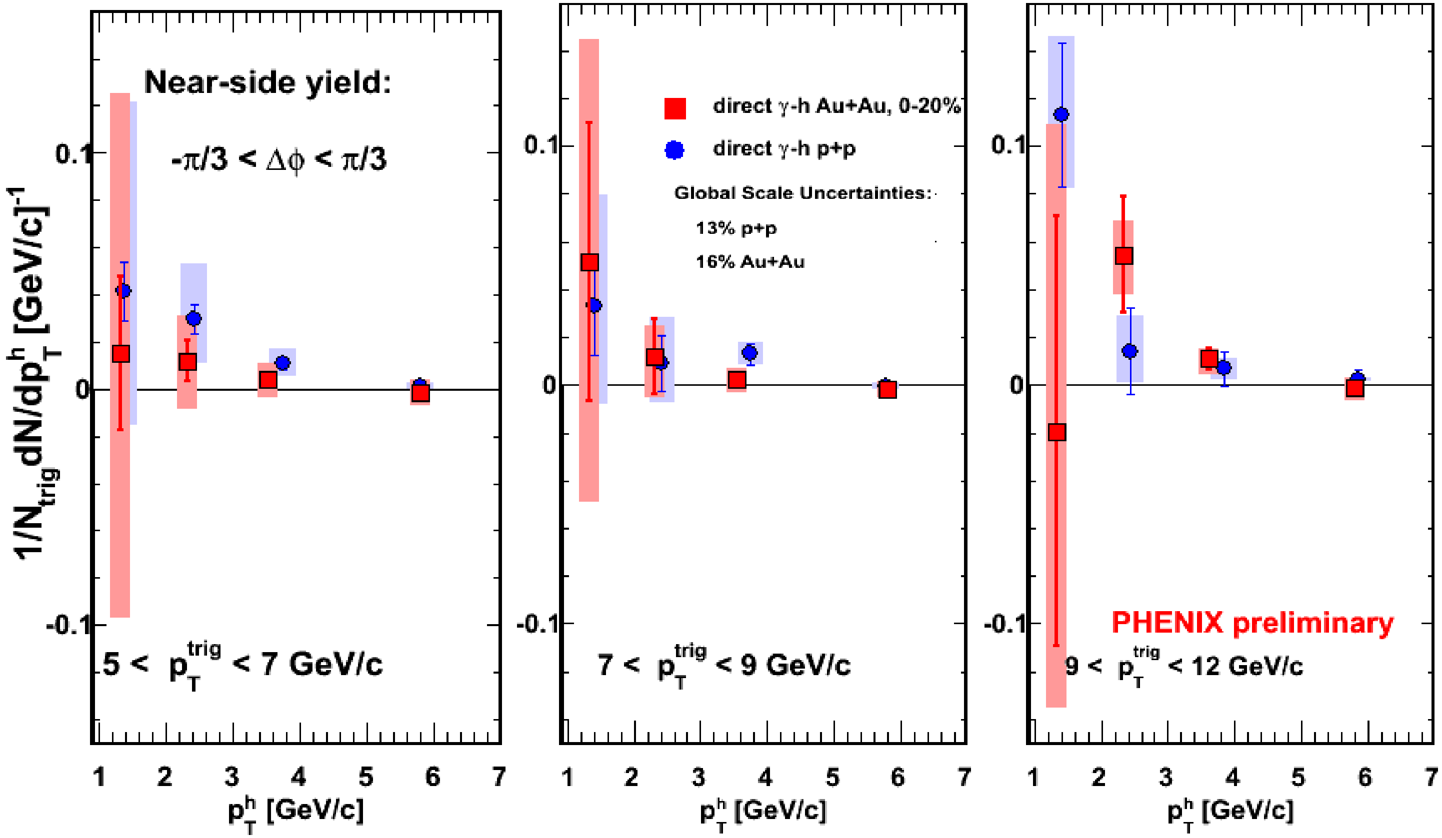


- π^0-h I_{AA} is above the π^0 R_{AA}

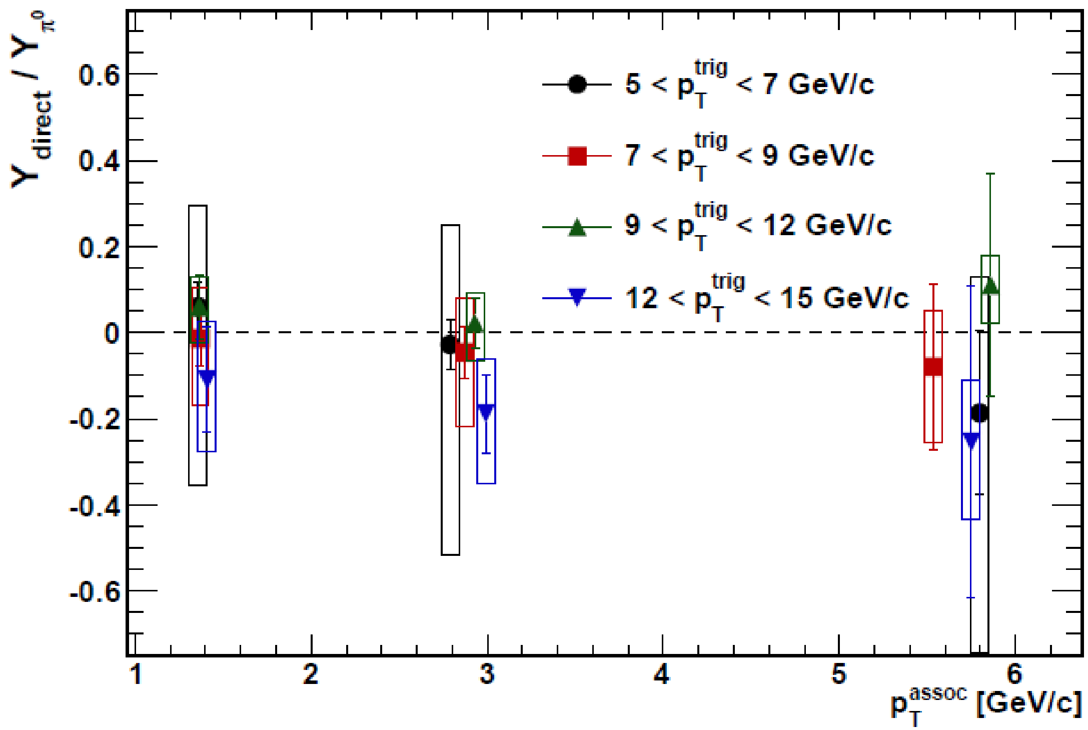
A. Adare et al. PRL 104, 252301 (2010)

Near Side Story

- Approximately zero direct γ–h yield in Au+Au
- No enhancement compared to p+p direct γ–h



NearSide Yield for isolation cut in p+p



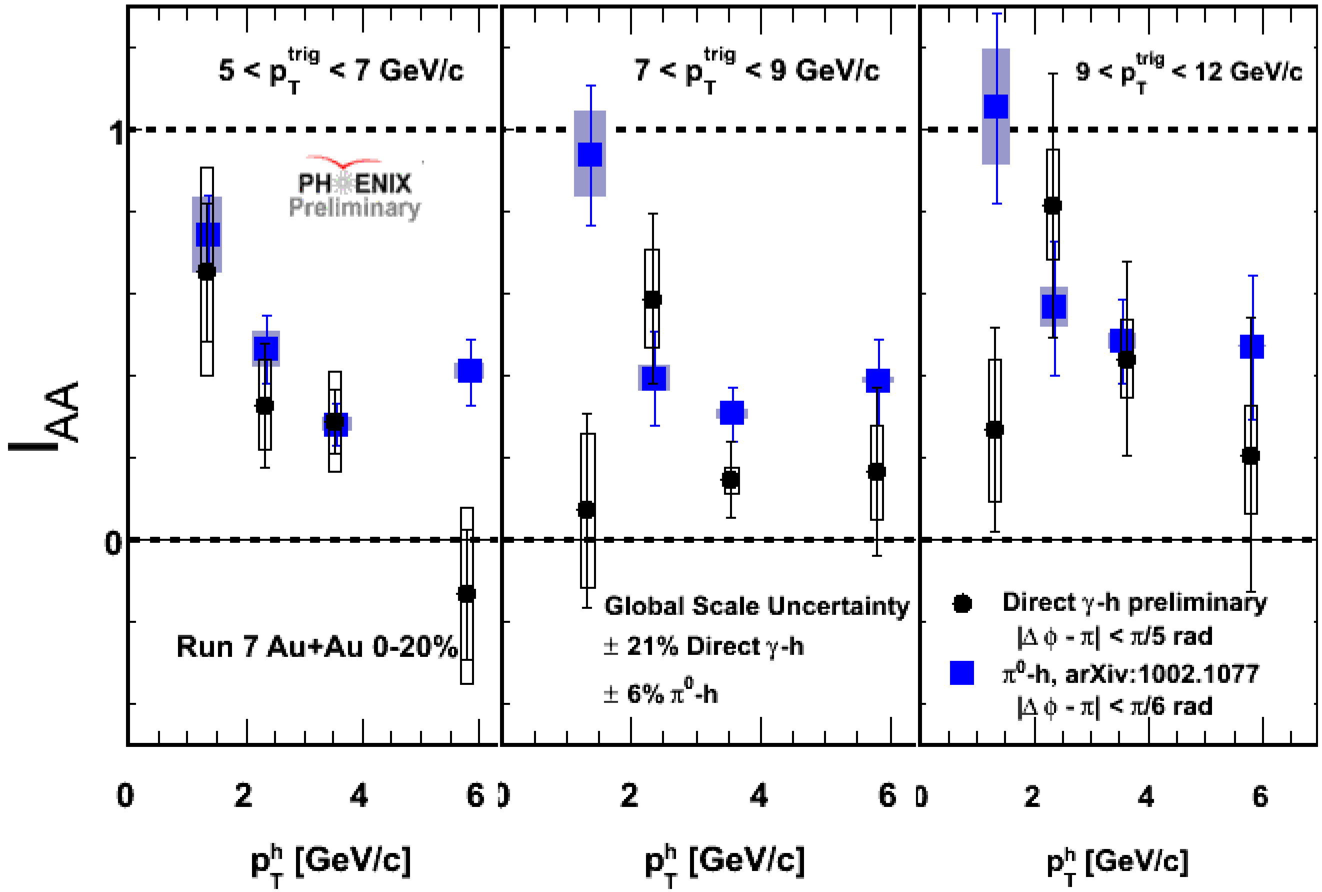
Effect of isolation cut in p+p

$$R_\gamma = \frac{N_{incl}}{N_{decay}}$$

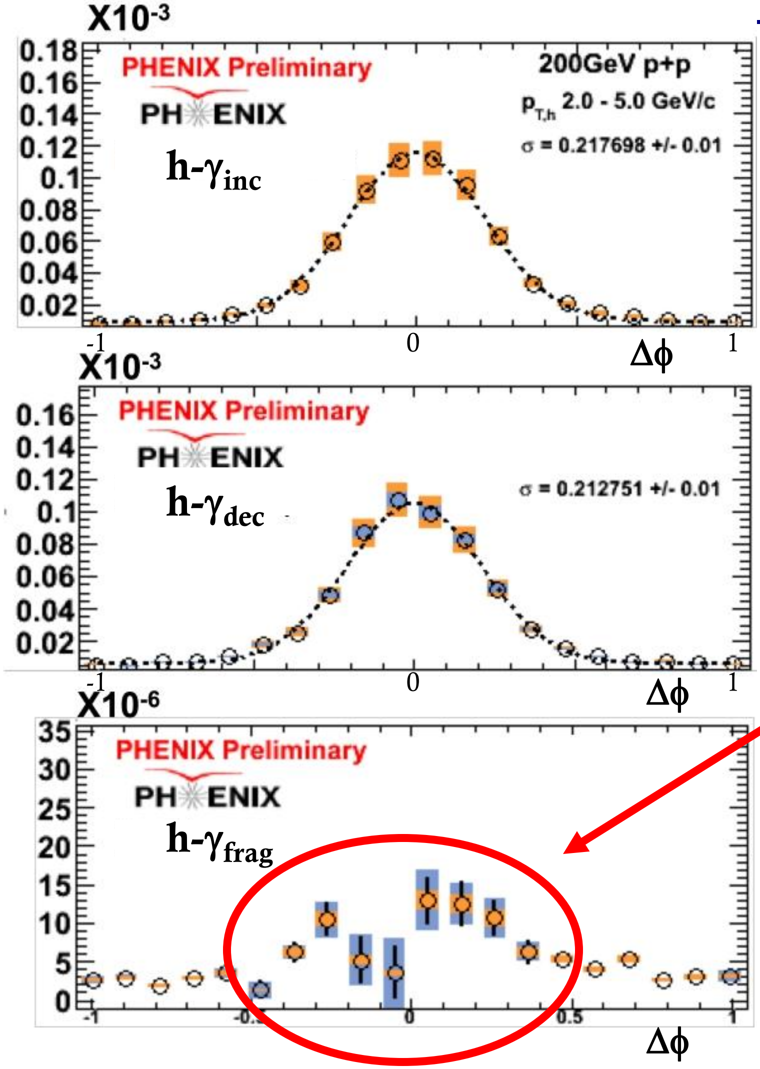
p_T [GeV/c]	R_γ	R_γ^{miss}	R_γ^{iso}
5-7	1.19 ± 0.06	1.32 ± 0.11	1.38 ± 0.12
7-9	1.33 ± 0.05	1.67 ± 0.13	1.92 ± 01.4
9-12	1.54 ± 0.05	2.22 ± 0.18	2.87 ± 0.22
12-15	1.80 ± 0.11	2.69 ± 0.36	4.02 ± 0.50

Compare to π^0-h

- Similar suppression in direct γ-h and π^0-h!



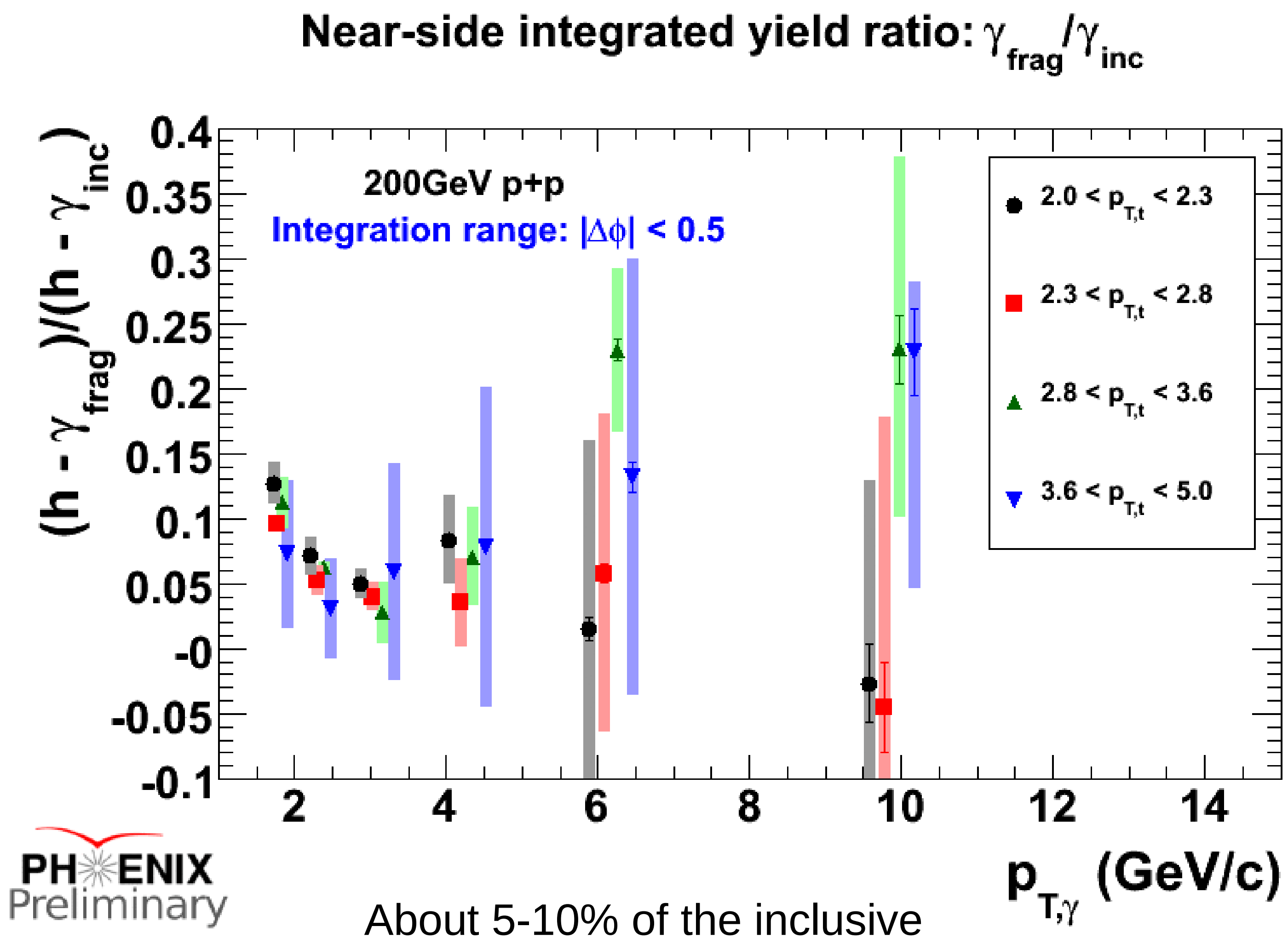
Measuring fragmentation photons in p+p



$$Y_{\gamma frag}(\Delta\phi) = Y_{\gamma inc}(\Delta\phi) - Y_{\gamma dec}(\Delta\phi)$$

- We see fragmentation photons!

$\gamma_{frag}/\gamma_{inc}$ in p+p



About 5-10% of the inclusive photons are from fragmentation!